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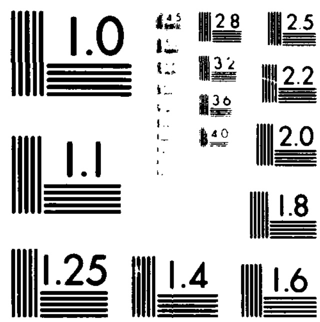

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FEDS SMOKE DISPERSION

Larry L. Paxson
American Service Products, Inc.
45 D Street, SE
Washington, D.C. 20003

31 August 1979

Final Report for Period 1 November 1978—31 August 1979

CONTRACT No. DNA 001-79-C-0017

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1. REPORT NUMBER: DNA 5064F ✓	2. GOVT ACCESSION NO.: AD-A084650
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): FEDS SMOKE DISPERSION	5. TYPE OF REPORT & PERIOD COVERED: Final Report for Period 1 Nov 78—31 Aug 79
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): Larry L. Paxson	8. CONTRACT OR GRANT NUMBER(s): DNA 001-79-C-0017
9. PERFORMING ORGANIZATION NAME AND ADDRESS: American Service Products, Inc. 45 D Street, SE Washington, D.C. 20003 ✓	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: Subtask B99QAXRB202-04
11. CONTROLLING OFFICE NAME AND ADDRESS: Director Defense Nuclear Agency Washington, D.C. 20305	12. REPORT DATE: 31 August 1979
	13. NUMBER OF PAGES: 22
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS (of this report): UNCLASSIFIED
	15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Nuclear Weapon Security
FEDS Taggant
Smoke Dispersion
Forced Entry Deterrent
Smoke Generation

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The report discusses the design and test of a Smoke Generator system for use in Forced Entry deterrence. The system is designed for rapid dispersion of opaque black smoke without excessive heat or sparks and is provided for magazine "safe" operation.

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PREFACE

The major task of the program was the development of smoke generation materials and the techniques to provide a smoke generator configuration that would conform to magazine safety standards, including operation in gas air mixtures within explosive limits. In the development of the smoke generation material, three primary techniques were investigated: (a) the use of flame retardant material; (b) adjustment of the heat of reaction by variation of the percentage of aluminum/ferric oxide; and (c) reduction of the burning rate of the smoke material by high pressure compaction. A total of four additives were tested and three mechanical designs were evaluated. The final configuration which was successfully tested is shown in figure 1.

A secondary task of the program was the development of special igniters for reliable activation of the HC material. The results of the igniters development are presented in Appendix 1.

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TABLE OF CONTENTS

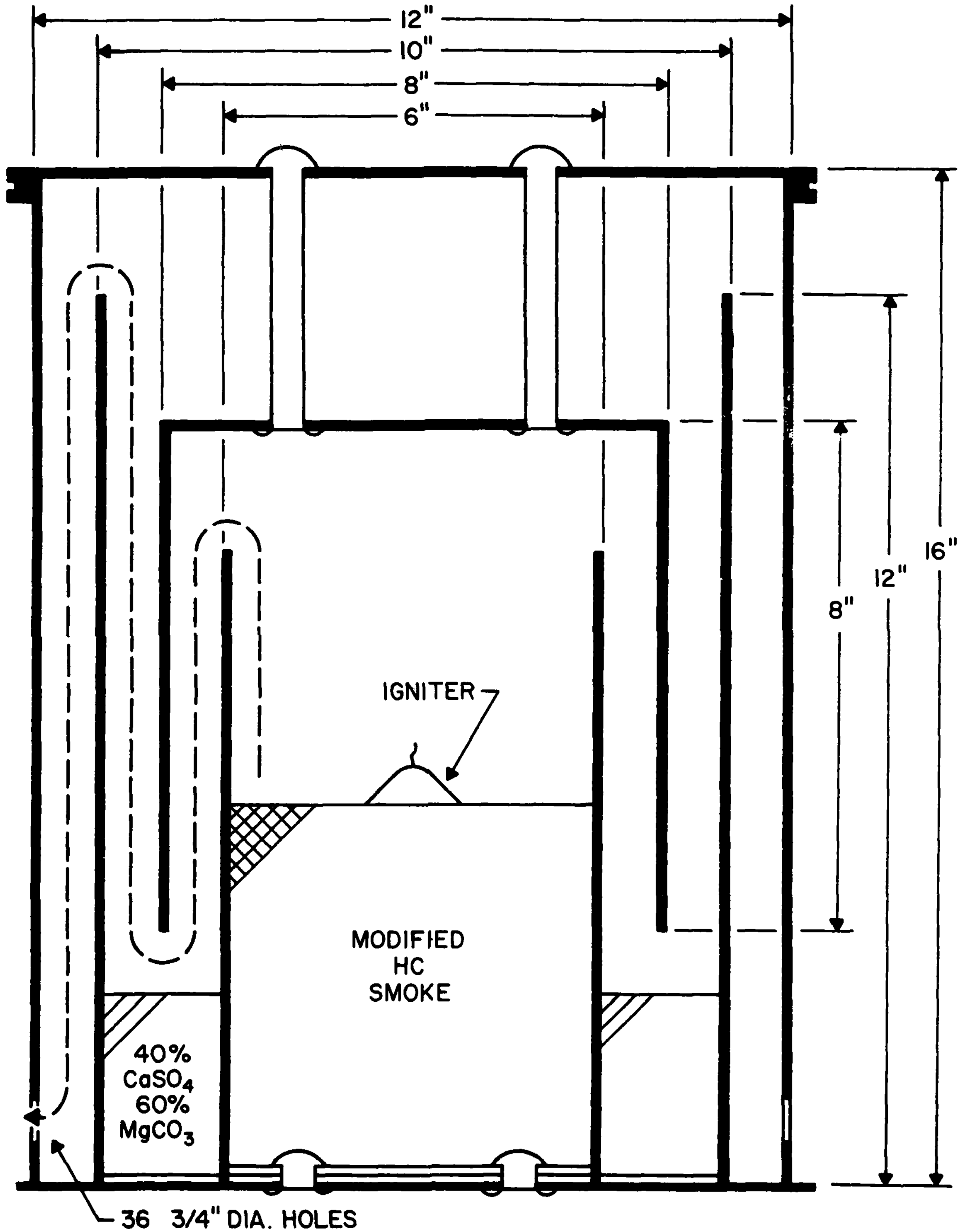
12"
10"
8"
6"
16"
12"
8"
IGNITER
MODIFIED
HC
SMOKE
40%
$CaSO_4$
60%
$MgCO_3$
36 3/4" DIA. HOLES

FIGURE I

SMOKE MATERIAL INVESTIGATION

Various chemical techniques were investigated in this phase of the program in order to provide a flameless smoke material. Mixtures of HC smoke incorporating such flame retardants as magnesium carbonate, calcium oxalate, hydrated alumina and ammonium oxalate were evaluated.

The series of 20 mixtures were tested. In each case a major problem was encountered in effectively curtailing the flame output without reducing the effluent smoke to a degree where the devices were tactically inefficient.

The incorporation of a small amount of flame retardant in excessive sparking in the smoke reaction process; as the flame retardant was increased, the reaction transitioned to a white smoke media due primarily to the generation of CO_2 and water vapor from the flame retardant materials. On the basis of these early results it was decided to utilize burning rate modification techniques rather than chemical additives to reduce the violence of the reaction.

PROTOTYPE TESTS - CHEMICAL

On the basis of the data accumulated during the chemical investigation phase, a series of smoke generator designs were developed and tested.

The primary criteria for the designs were: (a) large volume generation of smoke with maximum opacity; (b) ability to safely function in an explosive and flammable atmosphere; (c) minimum potential cost in production.

In a 10 x 10 foot chamber with a 12 foot ceiling, smoke opacity was estimated by the time and degree of obscuration of a 300 watt spotlight mounted in the end of the chamber.

The magazine safety potential was tested using a small butane torch impinging on the smoke output ports. Prior to smoke generator ignition, the torch valve was opened to the fuel rich flame position and mounted in place. If at the end of the smoke generation cycle the torch have not been ignited from the emergency smoke, the test was considered successful.

A series of 15 tests were conducted using various: (a) additives; (b) HC densities and mixtures and (c) mechanical configurations.

In the first test a standard HC material was tested in a 10" diameter, 10" high can lined with a calcium sulfate insulation. This shot was primarily to establish a benchmark of a typical HC configuration.

The second shot utilized a 10" diameter, 10" tall can with a 2" diameter tube mounted above the can to act as a manifold for the smoke. The manifold consisted of a 5 foot vertical tube capped with an 180° elbow, and an additional 5 foot extension was downward mounted. Although the device produced effective smoke, the high velocity smoke exiting from the tube still showed a high percentage of incandescent particles which would preclude the use of this geometry in a magazine safe environment.

Shots three and four utilized a similar configuration with two different percentages of magnesium carbonate incarcerated in the HC mixture. In one case the magnesium carbonate failed to alleviate the problem of the incandescent particles and in the second case the decomposition of magnesium carbonate resulted in a high percentage of CO_2 and water vapor in the smoke which eliminated its effective screening capability.

Shot five utilized a hydrated alumina additive and again we encountered a problem similar to the magnesium carbonate. Shots six and seven utilized calcium oxalate and again a similar problem occurred. A final two shot series was attempted with ammonium oxalate, and again similar problems were encountered.

PROTOTYPE TESTS - MECHANICAL

On the basis of these tests, it was decided that the primary means of achieving a magazine safe smoke generation system would be dependent on mechanical means coupled with a control of the burning rate of the HC smoke mixture.

The burning rate control was achieved by a combination of two factors: (a) compaction of the smoke generation material at various densities to provide control of the HC burning rate; (b) control of the flame temperature of the material through the regulation of a percentage of aluminum/ferric oxide to the HC smoke generation material.

A further step was the attempted utilization of a filtering bed of various flame retardant materials which was hoped would provide a means of reducing the incandescent particles without degradation of the smoke.

Shots seven and eight were attempted with a filtering bed of hydrated alumina; in one case a 2" loose bed, and in the second case a 1" loose bed, and both cases resulted in severe degradation of the smoke. Shots nine and ten were repeated utilizing a magnesium carbonate bed and again smoke degradation occurred.

In shots 11 and 12 it was decided to utilize a highly compacted anthracene/hexachloroethane smoke generation material utilizing aluminum/ferric oxide as a heat source for smoke. The first shot in this series was a mechanical configuration referred to as a two stage generator wherein the smoke was generated in one can and passed through a larger can and vented through the bottom of the can. In test two, the two stage generator showed incandescent sparks being discharged. For this reason we proceeded to the three stage can shown in figure 1 and in shots 13, 14 and 15, all tests demonstrated the required degree of magazine safety.

In the final three shots a special butane torch configuration was utilized. In earlier shots, a standard butane torch was placed at the base of the can and prior to ignition the butane torch was turned on and directed at the venting holes of the smoke generator. A test was considered successful when the torch did not ignite during the course of the smoke discharge. In the last three tests, a conventional butane torch equipped with a special manifold with four flame outlets was placed in a position which provided direct discharge of the gas on the series of smoke vents around the can. The manifold was utilized in all tests of the three stage can, and in all tests, the butane torch did not ignite during the smoke generation cycle.

The major problem encountered with the three stage can design is a considerable delay between the ignition of the HC discharge and the beginning of smoke dispersion. The delay is due to the fact that the smoke generation materials tested have relatively high flame temperatures. Therefore, the materials must be compressed to extremely high density to maintain the slow burning rate necessary to alleviate the problem of incandescent particle generation.

In the event a more rapid smoke generation is required, further testing of alternate smoke generation materials should be considered.

The tests would be confined to the anthracene/hexachloroethane smoke generation system. However, the aluminum/iron oxide material utilized to generate a heat of activation of the smoke generation materials should be further investigated. A substitution of silicon, zinc, or boron metal for the aluminum materials should moderate the heat of combustion and still provide sufficient heat intensity to generate a smoke reaction in an anthracene/hexachloroethane mixture.

FUTURE RECOMMENDATIONS

It is felt that the feasibility of safe rapid dispersion of high opaque black smoke can be achieved under conditions such that the equipment could be safely utilized in both nuclear storage sites and conventional ammunition magazines. On the basis of preliminary tests, it appears that the problem of confining the combustion of a rapid smoke dispersion and safe operation of the prototype models in a gas air mixture within the explosive limit has been demonstrated.

However, any future program to develop operational hardware should include a "boost" phase smoke mixture. It is felt that the present aluminum/ferric/oxide/anthracene/hexachloroethane material when sufficiently compacted provides an excellent "sustained" phase smoke material.

In the current program lab sample tests of candidate "boost" phase material appeared to show promise. Candidates to be further evaluated for the "boost" phase would include loosely packed anthracene/hexachloroethane mixture of silicon, zinc, boron metals in combination with iron oxide to provide the energy of activation.

It is felt that a small amount of these materials in loose form placed above the high compacted sustained phase HC mixture will provide for rapid dispersion of a deterrent smoke material, under magazine safe conditions.

COST CONSIDERATION

One of the major advantages of the system is the potential for a low production cost of operational hardware. Although we have not derived a formal estimate of the cost, all of the smoke generators have been fabricated from either commercially available paint can type containers, or Marmot clamp type containers which are available from the GSA supply. Both the "paint can type" and "Marmot clamp type cans" can be purchased to federal specification and are commercially available at reasonable prices.

The manufacture of the smoke pack consists of pressing of the smoke charge, mounting of a small initiator, and assembly of cans in the proper configuration. No machine work or costly assembly techniques are required.

APPENDIX 1

INITIATOR DEVELOPMENT

The primary purpose of the initiator development effort was to:

(a) Establish the feasibility of ignition of the modified HC material.

(b) Establish the delay times.

(c) Establish the feasibility of ignition from delay column to HC initiation mix.

A series of ignition formulations were tested. The final candidate material, a combination of metallic boron, zirconium, and ferric oxide were selected for use in both the instantaneous and delay initiators. This material proved effective in the initiation of the HC material and also receptive to the thermal stimulus of the delay material.

The second major effort under this task was the selection of a reproducible accurate delay material that was compatible with the HC initiator material and the bridge wire ignition mix. A further effort under this task was the design of the delay initiator. The material selected for this program was a combination of metallic tungsten powder and barium chromate. The material was incorporated in the delay column and because of the gaseous nature of the combustion process an indirect vented delay was designed. The use of indirect venting does not complicate the manufacturing process, but provides for a much more reproducible delay than the closed column delay materials that were investigated.

The delay columns were tested utilizing a standard ordnance test procedure. In the test procedure, the squibs were mounted on special fixture with a .002" wire stretched across the face of the output charge. The wire was mounted under spring tension and connected to a Hewlett Packard XY Plotter. Behind the .002" wire was a sheet of the plastic bonded (PBI) initiation material. On initiation, the delay column burned for the prescribed length of time, and on the ignition of the output charge the resistance wire was burned through and the "break" time measured. In addition to time measurement, the PBI material backing up the wire was checked to ensure successful ignition. Figure 1 shows the squib test set-up, and Figure 2 is a schematic of the test instrumentation.

The instantaneous squibs were tested in both series in parallel firings. The results of the instantaneous tests were visually monitored and the tests were considered successful if ignition of the PBI receptor charge was successfully ingited.

The results of the test of the time delays are shown in Table I with traces of the XY plots shown in figure 1. In view of the demonstrated reliability achieved in the instantaneous delays, only six* firings were required to establish the delay column design parameters. Shots one through seven represent the experimental prototype firings. Shots eight through ten represent the qualification firings, and the delay times ranged from a minimum of 29.0 secs. to a maximum of 31.0 secs.

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* Shot number four was successfully fired, however the timing instrumentation failed to function.

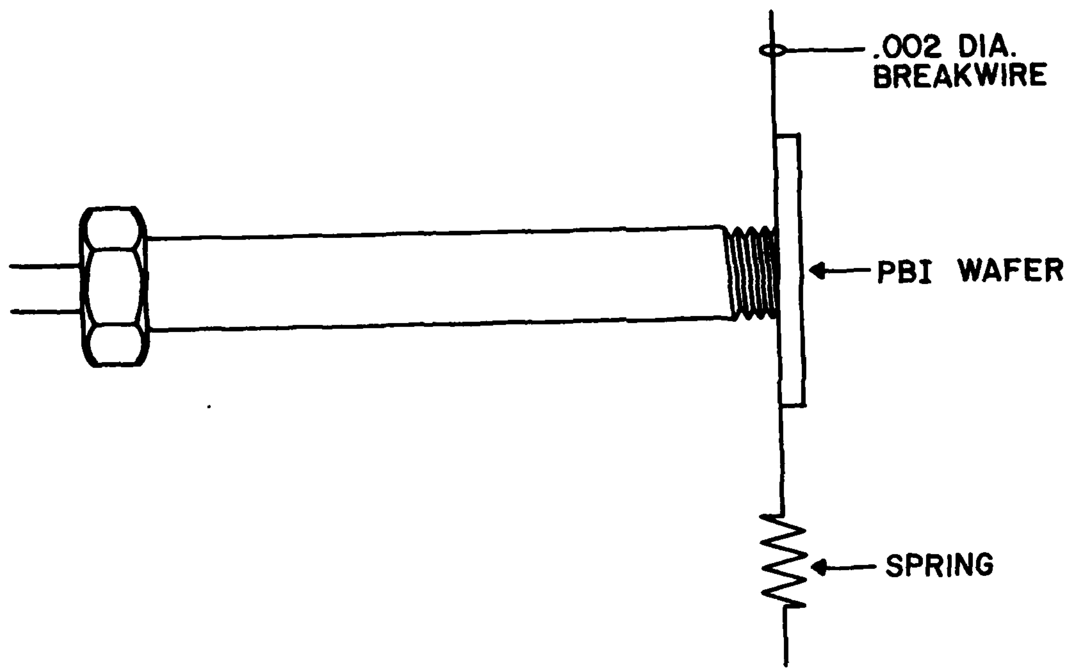

FIGURE 1
DELAY TEST SET UP

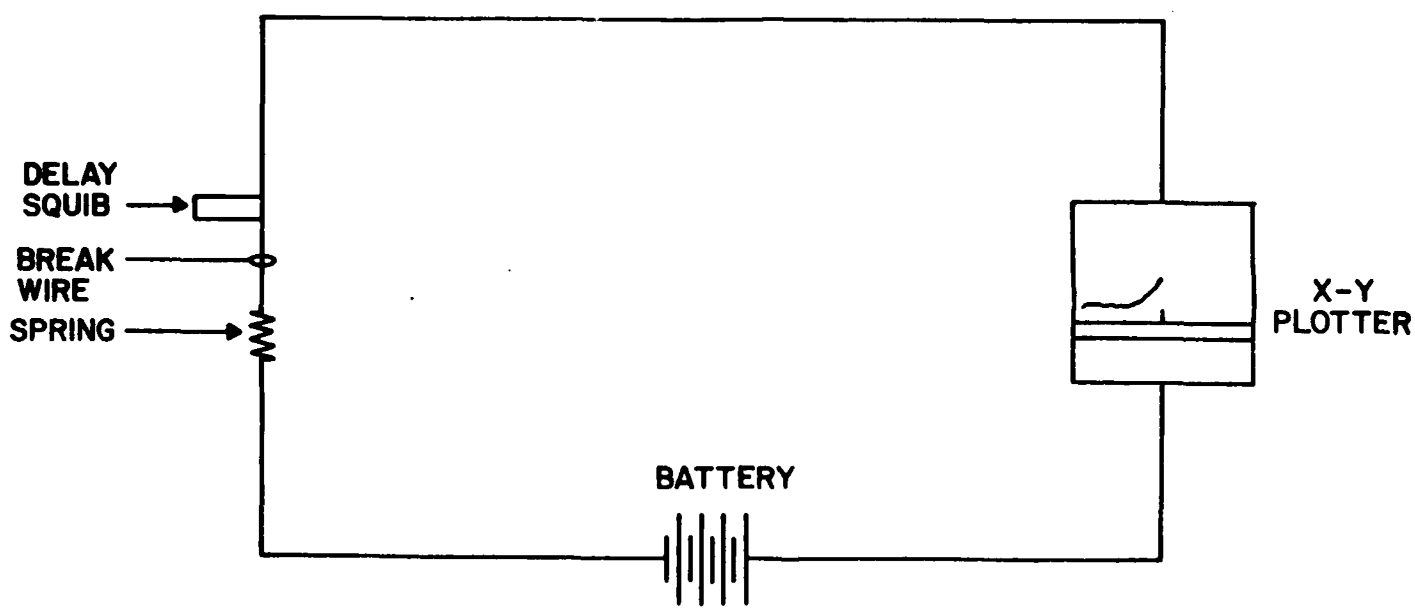

FIGURE 2
INSTRUMENTATION SCHEMATIC

TABLE I

Shot No.	Time/Second
1	46
2	21
3	27
4	--
5	27
6	28
7	28
8	29
9	29
10	29
11	30
12	30
13	30
14	29
15	30
16	30
17	31
18	30
19	30
20	30

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